Improved cooling for an electric motor or generator.

The present invention concerns an improved cooling of an electric motor or generator, more particularly what is called a "slotless" permanent magnet motor or generator.

It is known that such a "slotless" permanent magnet motor or generator is mainly composed of a housing and, in this housing, what is called a "slotless" tubular stator lamination with a smooth inner wall and electric windings wound in or around said tubular stator lamination on the one hand, and a rotor which is provided with permanent magnets on the other hand.

Such motors and generators which are equipped with a cooling formed of a cooling jacket provided on the outside of the stator through which cooling fluid flows is already known.

A disadvantage of such known stators is that the cooling at the rotor is often insufficient.

It is also known that "slotless" permanent magnet motors or generators are often provided with an air cooling, whereby air is blown over the winding heads of the stator by means of an external fan or by means of a screw or blades in one or other form, fixed on the

rotor.

This principle of air cooling can be applied on every winding head at each far end of the stator, as well as in order to realise an air flow from the winding head at one far end of the stator to the winding head at the other far end of the stator, via the air gap between the rotor and the stator, as well as in order to realise an air flow from the middle of the stator in the air gap, axially to the winding heads at the far ends, to thus cool the rotor shaft and the winding heads.

Instead of air, it is also known that other gases can be applied as a cooling medium.

A disadvantage of such cooling by means of air or another cooling gas is that, in both cases, it is very difficult to build a motor which is entirely closed in view of a dust-free or moisture-free operation.

In exceptional cases, as known for example from WO 01/35513 and US 5,304,883, direct oil cooling of the stator winding is known, whereby the live conductors of the stator winding are in direct contact with the oil, as a result of which there is a potential risk of possible short circuits.

Direct cooling through the rotor is also one of the known motor designs, but it is complex and expensive.

In the case of permanent magnet motors or generators with a higher speed and higher capacity of what is called the "surface mounted" type, the magnets are fixed on the rotor shaft and held on the rotor shaft by means of a tube which has to absorb the centrifugal forces at a high rotational speed and which is made of metal or of carbon fibres, which tube is provided with a large pre-stress around the magnets, such that the torque can also be transmitted at the maximum rotational speed.

Such motors or generators which are designed to operate at high speeds, are always as small as possible because of among others mechanical and rotor-dynamical aspects. As a result, the energy density in the stator may form a problem and require a special cooling concept, for as the stator heats up too much, this may result in an unwanted temperature raise in the rotor. When the stator is too hot, and due to air in the air gap, it becomes more difficult for the rotor to give off this heat, and the rotor may also be additionally heated by the stator. Especially when the above-mentioned tube which holds the magnets on the rotor is made of carbon fibres, a heating of the rotor may have disastrous consequences.

Some known permanent magnet motors and generators moreover require an extra cooling of the rotor, which can be realised for example by means of an air cooling through the air gap between stator and rotor or through the shaft. In order to remedy all the above-mentioned difficulties, a complex, expensive and sizeable cooling circuit is usually required. Also, an entirely closed permanent

magnet motor or generator cannot be realised in a simple manner, and the cost price of such a motor or generator is usually very high.

Another major disadvantage of the present known permanent magnet motors or generators, for example as in the case of the above-mentioned WO 01/35513 and US 5,304,883, is that providing the windings is very laborious, time-consuming and expensive, since the "slotless" stator lamination in this case has a smooth inner wall without any teeth, around which the windings can be wound, as in the case of motors or generators with a conventional stator lamination.

The present invention aims to remedy the above-mentioned and other disadvantages.

To this end, the invention concerns an improved cooling of an electric motor or generator consisting of a housing, what is called a "slotless" tubular stator lamination, a rotor with permanent magnets and electric windings provided between the stator lamination and the rotor, characterised in that the cooling comprises a cooler which is provided between the stator lamination and the rotor and in that the windings are provided on this cooler.

An advantage of such a motor or generator according to the invention is that the cooling is applied in the immediate environment of the rotor and of the windings of the stator, as a result of which a very efficient

cooling of the rotor with its magnets and the tube which holds the magnets on the rotor, as well as of the stator windings is obtained.

Another advantage is that such a motor or generator with an internal cooling is more compact than a known motor or generator with an external cooling jacket and a comparable capacity.

Another advantage is that, since the cooling is provided internally in the stator, such a stator can be used for closed motors or generators which are applied for example in dusty and damp environments or in environments with flammable or corrosive gasses.

The above-mentioned cooler is preferably provided with radial teeth directed towards the rotor which extend in the axial direction of the stator and in between which axially directed grooves are defined, such that the cooler has an external shape of a conventional stator lamination.

An advantage of such a cooler is that the above-mentioned windings can be provided in a very simple manner in the above-mentioned grooves around the above-mentioned teeth, more particularly in the same manner as in the case of the conventional asynchronous or synchronous motors and generators which are provided with a stator lamination with teeth.

An advantage linked thereto is that such a stator can be manufactured at low cost and moreover can also be easily produced in series by applying the known full-automatic winding techniques applied with conventional motors and generators.

Another advantage is that such a cooler can also be manufactured via an automated process, for example by means of extrusion, die-casting, stereo lithography or the like.

In order to better explain the characteristics of the invention, the following preferred embodiments of a motor or generator with an improved cooling according to the invention are described as an example only, without being limitative in any way, with reference to the accompanying drawings, in which:

figure 1 schematically represents a stator of a motor or generator with an improved cooling according to the invention in perspective;
figure 2 represents a section according to line II-II in figure 1;
figure 3 represents the part indicated by F3 in figure 2 to a larger scale;
figure 4 represents a section according to line IV-IV in figure 1;
figure 5 represents a section according to line V-V in figure 4;
figure 6 represents a first variant according to figure 1;

figure 7 represents a section according to line VII-VII in figure 6;
figure 8 represents a section according to line VIII-VIII in figure 7;
figure 9 represents a second variant according to figure 1;
figure 10 represents a section according to line X-X in figure 9;
figure 11 represents a section according to line XI-XI in figure 10;
figure 12 represents a third and last variant according to figure 1;
figure 13 represents a section according to line XIII-XIII in figure 12;
figure 14 represents a section according to line XIV-XIV in figure 13.

Figures 1 to 5 represent a stator 1 of a motor or generator with an improved cooling according to the invention, whereby the motor or generator is more particularly of the type which is equipped with a rotor 2 with permanent magnets, which rotor 2 is only represented schematically in figures 2 and 3 by means of a dashed line, for clarity's sake.

The stator 1 in this case consists of a tubular housing 3 in which is provided a tubular stator lamination 4 with a predominantly smooth inner wall 5, i.e. with an inner wall 5 without any pronounced grooves or teeth.

Between the stator lamination 4 and the rotor 2 is provided a cooler 6 through which a cooling fluid can be guided and which mainly consists of a cooling element 7 which is connected to an outlet collector 8 on one far end and which is connected to an inlet collector 9 on the other far end.

The cooling element 7 is formed of a double-walled tube with an outer cylindrical tube 10 whose outer diameter corresponds to the inner diameter of the stator lamination 4 and an inner corrugated tube 11 whose corrugations are such that they form radial teeth 12 directed towards the rotor which extend in the axial direction and in between which axially directed grooves 13 are defined.

The above-mentioned teeth 12 and grooves 13 are preferably evenly distributed over the inner perimeter of the cooling element 7.

The outer tube 10 and the inner tube 11 are connected to each other by means of partitions 14 which form passages 15 for a cooling fluid together with the outer and the inner tube 10-11.

In the given example, the cooling element 7 is just as long as the stator lamination 4.

The outlet collector 8 as well as the inlet collector 9 are formed of a ring-shaped element which is formed of a cylindrical outer wall 16 which is provided on one far end of the stator 1 in the housing 3 up against the

stator lamination 4; a corrugated inner wall 17 which extends up against and in the prolongation of the corrugated inner tube 11 of the cooling element 7; a sealing wall 18 which connects the above-mentioned outer wall 16 to the inner wall 17; and a side wall 19 which is connected to a far end of the cooling element 7 in the axial direction and which has been partially worked open at the above-mentioned passages 15.

In the above-mentioned outer wall 16 of the outlet collector 8 is provided an opening 20 situated opposite to an outlet opening 21 in the housing 3, whereas in the outer wall 16 of the inlet collector 9 is provided an opening 22 opposite to an inlet opening 23 in the housing 3, which outlet and inlet openings 21-23 are provided for connecting a cooling circuit which is not represented in the figures.

In the given example, the walls of the grooves 13 of the cooler 6 are coated with an electrically insulating film or layer 24, called slot insulation.

Around the teeth 12 of the cooler 6 are provided electric windings extending with axial parts 25 in the above-mentioned grooves 13 and which have bent parts 26 at the far ends of the cooler 6 which are schematically represented by means of a dashed line in figure 1 and which are bundled together or tied together in the known manner into what is called a ring-shaped winding head 27 on every above-mentioned far end of the stator 1.

The above-mentioned windings 25-26 can be wound in the same manner, thanks to the toothed design of the cooler 6, as in the case of the known conventional motors and generators which are equipped with a stator lamination with teeth and grooves in which the windings are provided.

In this manner, for the winding of a stator 1 according to the invention, use can be made of installations which could only be used until now for the automatic winding of conventional synchronous and asynchronous motors and generators.

It is clear that, in the case of the invention, providing windings 25-26 in the grooves 13 of the cooler 6 is much simpler than was possible until now with stators of the type having a stator lamination with a grooveless smooth inner wall.

The far ends of the stator 1 are preferably sealed by means of heat-conducting and electrically insulating paste 28, for example a paste on the basis of epoxy or silicones which is cast on the winding head 27 and against the cooler. A tube which fits exactly in the inner diameter of the stator is hereby put in the stator, for example, and the thermally conducting paste is cast up to a height equal to that of the housing. The paste 28 makes contact with the sealing wall 18 of the outlet collector 8, the inlet collector 9 respectively on the one hand, and with the winding head 27 on the far end concerned on the other hand.

The cooler 6 is preferably made of a heat-conducting and electrically insulating material as well.

The use and working of a stator 1 with an improved cooling according to the invention to be applied in a motor or generator is analogous to those of the known embodiments, with this difference that the stator 1, in the case of the invention, is connected to an external cooling circuit via the outlet and inlet openings 21-23 in the housing, as a result of which a cooling fluid flows via the outlet collector 8 through the passages 15 in the cooling element 7 to the inlet collector 9.

As a result, the stator 1 and the windings 25-26 of the stator 1 are cooled directly, and the zones around the rotor 2 and the air in the air gap between the stator 1 and the rotor 2 are cooled indirectly, which has a favourable effect on the temperature, guaranteeing a longer life. In the case of a closed motor, this idea can make the difference between a feasible and a non-feasible embodiment of the motor or of the generator.

It is clear that the inside of the motor or of the generator do not get into contact with the "outside world", as no air has to be sucked in to be blown over the winding heads or between the air gap. The motor housing is sealed on the bearing plates, which are not represented here, and which in this manner seal the motor entirely.

As a result, such a motor or generator according to the invention can be used in dusty and moist circumstances without any problem.

Figures 6 to 8 represent a variant of a motor or generator with an improved cooling according to the invention, which is built in an analogous manner as the above-described embodiment, but whereby the cooler 6 is made in another manner.

The cooling element 7 of the cooler 6 is in this case formed of a series of axially directed pipes 29, which are provided at a mutually equal distance from each other and at a mutual distance from the stator lamination 4, and which are held between two ring-shaped flanges 30 which are fixed in the stator lamination 4.

In the flanges 30 are provided passages 31 opposite to the far ends of the above-mentioned pipes 29, whereas in the inner edge of the flanges 30 are provided grooves 32 which are confined by radially inwardly directed teeth 33 situated at equal distances from each other.

The pipes 29 extend in the radial direction up between the grooves 32 and they form passages 15 for a cooling fluid.

The windings 25-26 are provided in the grooves 32 with their axial parts 25.

The cooling element 7 is further formed of a filling material 35 which is thermally conductive and preferably also electrically insulating and which is provided in the space which is confined by the stator lamination 4, the flanges 30, the pipes 29 and the axial parts 25 of the windings 25-26.

In this manner, teeth 12 are formed so to say by the filling material between the axial parts 25 of the windings 25-26.

In the embodiment of figures 6 to 8, the outlet and inlet collectors 8-9 are formed of a similar, ring-shaped element as in the embodiment of figure 1, but whereby, in this case, a recess 36 is provided in the inner wall 17 turned towards the rotor 2, in which recess the winding head 27 is cased on the far end concerned of the stator 1 and whereby the space between the winding head 27 and the collector 8-9 concerned is preferably filled with a similar filling material 35, as described above.

The working and use of a motor or generator with an improved cooler according to the last described embodiment is entirely analogous to that of the first embodiment, with this difference that, because of the form of the outlet and inlet collector 8-9, the winding heads 27 concerned are better cooled, since they are enclosed by said collectors 8-9 for a large part, without the cooling medium getting into direct contact with the live guides of the windings however.

Figures 9 to 11 represent a variant of a motor or generator with an improved cooling according to the invention, with a cooling element 7 which is similar to that of figure 6, but whereby two series of axially directed pipes 29 are provided in this case and whereby the pipes 29 of one series are situated at a larger distance from the stator lamination 4 than the pipes 29 of the other series.

The inlet and outlet collectors 8-9 are in this case formed of a ring-shaped chamber 37 which is confined by the housing 3; of the cooling element 7; of an inner tube 38 which has been provided concentrically in the cooling element 7; and of a ring-shaped lid 39 or which is connected to the housing 3 and to the above-mentioned inner tube 38 by means of sealings 40 and 41.

It is clear that the winding heads 27 are in direct contact with the cooling fluid in this case which flows into the collector 9 via the inlet opening 23 and which leaves the outlet collector 8 via the outlet opening 21, such that, in this case, the cooling of the winding heads 27 will be even more efficient than in the case of the above-described variants.

Figures 12 to 14 represent another variant of an improved stator 1 which is similar to that of figure 9, but whereby the cooling element 7 has been replaced by a cooling element such as that of figure 1.

It is clear that also other combinations are possible of

a cooling element 7 according to one of the above-described types with outlet and inlet collectors 8-9 in the form of a ring-shaped element or of a ring-shaped chamber 37, as described above.

It is also possible that the cooler 6 is made in one piece, whereby the cooling element 7 and the outlet and inlet collectors 8-9 are integrated in one and the same element.

The present invention is by no means limited to the embodiments described as an example and represented in the accompanying drawings; on the contrary, such a motor or generator with an improved cooling according to the invention can be made in all sorts of shapes and dimensions while still remaining within the scope of the invention.

Claims.

1.- Improved cooling of an electric motor or generator consisting of a housing, what is called a "slotless" tubular stator lamination (4), a rotor (2) with permanent magnets and electric windings (25-26) which are provided between the stator lamination (4) and the rotor (2), characterised in that the cooling comprises a cooler (6) which is provided between the stator lamination (4) and the rotor (2) and in that the windings (25-26) are provided on this cooler (6).

2.- Improved cooling according to claim 1, characterised in that the cooler (6) is provided with teeth (12) directed radially towards the rotor (2) which extend in the axial direction of the stator (1) and in between which axially directed grooves (13) are defined, such that the cooler has an external form of a conventional stator lamination.

3.- Improved cooling according to claim 2, characterised in that the above-mentioned teeth (12) and grooves (13) are evenly distributed over the inner perimeter of the cooler (6).

4.- Improved cooling according to claim 2, characterised in that the above-mentioned windings (25-26) are provided around the above-mentioned teeth (12),

whereby these windings (25-26) have axial parts (25) which extend in the above-mentioned grooves (13) and bent parts (26) which are bundled together into what is called a winding head (27) on both far ends of the stator (1).

5.- Improved cooling according to claim 1, characterised in that the cooler (6) is formed of a cooling element (7) with one or several passages (15) for a cooling fluid.

6.- Improved cooling according to claim 5, characterised in that the above-mentioned passages (15) are axially directed and are connected to an outlet collector (8) on one far end of the stator (1) and to an inlet collector (9) on the other far end of the stator (1) respectively.

7.- Improved cooling according to claim 5, characterised in that the above-mentioned cooling element (7) is formed of a double-walled tube with an outer tube (10) and an inner tube (11).

8.- Improved cooling according to claim 7, characterised in that the outer tube (10) is a cylindrical tube whose outer diameter corresponds to the inner diameter of the stator lamination (4), whereas the inner tube (11) is a corrugated tube with axially directed teeth (12) and grooves (13), whereby the outer and the inner tubes (10-11) are connected to each other

by means of partitions (14) which, together with the outer and the inner tubes (10-11), define the above-mentioned passages (15) for the cooling fluid.

9.- Improved cooling according to claim 5, characterised in that the cooling element (7) is formed of axially directed pipes (29) which form the above-mentioned passages (15) and which are provided at mutually equal distances from each other between the stator lamination (4) and the rotor (2) and are cased at least with their far ends in two ring-shaped flanges (30) which are fixed in the stator lamination (4).

10.- Improved cooling stator according to claim 9, characterised in that at least a part of the above-mentioned pipes (29) are situated partially between the axial parts (25) of the above-mentioned windings (25-26).

11.- Improved cooling according to claim 9, characterised in that the above-mentioned ring-shaped flanges (30) are provided with teeth (33) which are radially directed towards the rotor, in between which the above-mentioned windings (25) are provided.

12.- Improved cooling according to claim 11, characterised in that the space between the pipes (29) and the axial parts (25) of the windings (25-26) is at least partially filled with a thermally conductive and electrically insulating filling material (35).

13.- Improved cooling according to claim 5, characterised in that the above-mentioned outlet and inlet collectors (8-9) are each formed of a ring-shaped element which confines a ring-shaped chamber (37), whereby this ring-shaped element is connected to a side wall (19) against a far end of the cooling element (7) and whereby this side wall (19) has been worked open at the above-mentioned passages (15) of the cooling element (7).

14.- Improved cooling according to claim 13, characterised in that each above-mentioned ring-shaped element is connected to the above-mentioned housing (3) with an outer wall (16) and in that at least one opening (20-21) is provided in this outer wall (16), which opening is situated opposite to an outlet opening (21), inlet opening (23) respectively, in the housing (3).

15.- Improved cooling according to claim 14, characterised in that in the above-mentioned ring-shaped element in the wall (17) directed towards the rotor (2) is provided a recess (36) in which the winding head (27) is cased on the far end concerned of the stator (1).

16.- Improved cooling according to claim 5, characterised in that the above-mentioned outlet and inlet collectors (8-9) are formed of a ring-shaped chamber (37) which is confined by the housing (3); of the cooling element (7); of an inner tube (38) which is provided concentrically in the cooling element (7); and of a ring-shaped lid (39) which is connected to the housing (3) and to the above-

mentioned inner tube (38).

17.- Improved cooling according to claim 16, characterised in that in the housing (3), at the height of the outlet and inlet collectors (8-9), is provided at least one outlet (21) or inlet opening (23) respectively.

18.- Improved cooling according to claim 1, characterised in that the cooler (6) is made of a thermally conductive and electrically insulating material.

19.- Improved cooling according to claim 1, characterised in that the cooler (6) forms a separation between the cooling fluid and the electric windings (25-26).